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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

TREE INJECTION AS A CONTROL OF  
THE MOUNTAIN PINE BEETLE  
IN WESTERN WHITE PINE  
1938 Investigation

by  
W. D. Bedard  
Associate Entomologist

Forest Insect Laboratory  
Coeur d'Alene, Idaho  
December 29, 1938

BUREAU OF

Entomology and Plant Quarantine

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Studies C-1B

Forest Insect Laboratory  
Coeur d'Alene, Idaho  
January 6, 1939

Dr. F. C. Craighead

Washington, D. C.

Dear Dr. Craighead:

I am enclosing two copies of an office report "Tree Injection as a Control of the Mountain Pine Beetle in Western White Pine - 1938 Investigation", by W. D. Bedard. One of these copies is for the files of your office, the other to be circulated or disposed of as you may see fit. Copies have been sent to Messrs. Miller, Keen, Beal, and Wilford.

In this year's report Mr. Bedard has gone rather thoroughly into the relationship of blue stain development in western white pine in relation to age of attack, on the basis that the success or failure of tree injection depends upon the amount of blue stain development. You will note that, contrary to our expectations, there was less blue stain in the upper portion of the tree than at the base. This difference may be explained by a difference in the age of attack in these two portions of the tree or in the rate of development.

We will be pleased to have your comments concerning this report and will attempt to give further information on any points not made entirely clear.

Respectfully yours,

James C. Evenden  
Senior Entomologist

Enclosures

TREE INJECTION AS A CONTROL OF  
THE MOUNTAIN PINE BEETLE  
IN WESTERN WHITE PINE

From 1930 to 1938 experimental injections of western white pine trees have been made with various poison solutions in an attempt to destroy broods of the mountain pine beetle which develop beneath the bark. The trees were always injected during the summer or fall of each year and examined in the spring of the succeeding year. Results of these injections have been submitted annually in report form<sup>1/</sup> so that only a brief summary of previous work need be given here.

During the years 1930, 1931 and 1932 most of the work was confined to determining the most effective poison and the most feasible technique of injection. During the six subsequent years, although improvements were made in the method of injection and new poisons were tested, most of the work was done to ascertain the results secured on large scale

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<sup>1/</sup>

- 1931 - St. George, R. A. and Gibson, A. L. Tree injection studies with lodgepole pine and notes on western white pine.
- 1933 - Gibson, A. L. and Bedard, W. D. Tree medication as a control of the mountain pine beetle in western white pine.
- 1934 - Bedard, W. D. Additional information concerning tree medication as a control of the mountain pine beetle in western white pine.
- 1935 - Bedard, W. D. Results of the 1934 tree medication experiments in western white pine.
- 1936 - Bedard, W. D. Tree medication as a control of the mountain pine beetle in western white pine. 1935 investigations.
- 1937 - Bedard, W. D. Tree injection as a control of the mountain pine beetle in western white pine. 1937 examinations.



projects. Briefly, these studies found that satisfactory results could be secured with sodium arsenate or copper sulfate solutions if the trees were injected before they had been infested for sixty days. If the trees had been attacked for a longer period, results varied from no control to 100 percent mortality. It was also found that by using the sawkerf-paper collar method of injection, and copper sulfate as the poison, tree injection was somewhat less than half as costly as present control methods.

The main difficulty with the method, and the fact which has prevented its adoption in actual control, is the tremendous variation in results and the consequent uncertainty of successful injection. Best results were secured in 1935, when a mortality of slightly more than 98 percent was secured. However, a duplication of the 1935 tests in 1937 resulted in an average mortality of only 46.1 percent, by far the poorest results ever secured.

This report deals with the 1937 work and summarizes a study of blue stain development in infested trees made during the 1936 season.

#### GENERAL RESUME OF INJECTIONS AND RESULTS

During the 1937 studies 180 trees were injected with varying amounts of copper sulfate in different concentrations of solution. The amount of copper was determined by administering one-quarter, one-half or one ounce of copper sulfate per inch breast high diameter. Each of these dosages was injected in two different concentrations of solution, namely 25 and 50 percent. The dosage of one-half ounce of poison in a twenty-five



percent solution is comparable to the 1935 dosage which gave such successful results. To check the 1936 commercial dosages, 10 trees were injected with eight ounces of copper sulfate per cubic foot of wood to be injected, and 20 additional trees were given one-half ounce per inch d.b.h. in a 25 percent solution by means of a deep saw cut, in order to test the feasibility of deep saw kerfs.

Table I shows the dosages administered, the mortality secured by each one, and the average of all probable pertinent factors influencing the success of the injection.

Considering averages of all the variable factors shown in table I, it is seen that no one shows sufficient variation to account for the spread in mortality which resulted from these injections. Blue stain varies only from medium to medium plus when averaged for all of the different dosages. Diameter shows a spread of only 4.4 inches and width of sapwood only .3 inch. Considerable range is apparent in growth, attacks per square foot, and age of attack, but no correlation is apparent when these are compared on the basis of average mortality.

Relative to dosages, table I indicates that the smaller amounts of copper sulfate resulted in the greatest mortality and although the differences are not great, the more concentrated solution in each of the three groups appears to have given best results. This is somewhat contrary to expectations, because it was believed that the less concentrated solution would provide more water and allow for freer passage around the blue stain. It is to be noted, however, that the commercial dosage, which was injected as a saturated solution, gave the poorest results.

TABLE I

GENERAL OUTLINE OF DOSAGES AND RESULTS WITH THE  
AVERAGE OF ALL PROBABLE PERTINENT FACTORS

Dosage	Average									
	Brood	Blue	Rings last	Rings	Rings in	Width	Attacks	Age of		
	Trees:	mortality:	stain	d.b.h.:	inch	last in.	sapwood	sapwood	per sq.ft.:	attack
	no.	percent		inches:	no.	no.	no.	inches	no.	days
50- $\frac{1}{4}$ <sup>a/</sup>	25	53.1	Medium+	15.7	18	29	31	1.1	8.6	59
25- $\frac{1}{4}$	25	50.2	Medium+	16.9	18	30	31	1.1	8.6	61
25- $\frac{1}{2}$ deep kerf	20	33.1	Medium+	12.6	16	30	33	1.1	15.0	41
25- $\frac{1}{2}$ shallow kerf	25	49.2	Medium+	12.5	22	35	33	1.0	12.4	54
50- $\frac{1}{2}$	25	53.4	Medium	15.8	13	26	31	1.2	9.7	54
25-1	25	36.0	Medium+	15.4	14	25	28	1.2	9.1	61
50-1	25	44.3	Medium	14.6	16	28	28	1.0	7.6	62
Heavy dosage	10	16.2	Medium	16.6	15	25	28	1.3	12.9	56

<sup>a/</sup> 50- $\frac{1}{4}$  - 50 percent solution with a dosage of  $\frac{1}{4}$  ounce per inch d.b.h. on the basis of 2 pounds copper sulfate per gallon of water.

## ANALYSIS OF RESULTS ACCORDING TO PROBABLE IMPORTANT VARIABLES

Although all of the known measurable variables have been included in this study, the lack of uniformity in results leads to the belief that some other factor or combination of factors has not yet been considered or that the measurement of the known variables is not sufficiently refined. In any event, the 1937 experiments show no more positive results than in former years and do not help to explain the confusing issues.

### Effect of Blue Stain

The blocking of conducting tissue by the hyphae of blue stain fungi is undoubtedly the most important limiting factor of this type of control. Table II shows the average mortality according to the amount of blue stain coloration at the point of injection. Unfortunately it is impossible to make an accurate determination of blue stain without destroying the tree for injection purposes. Consequently, in table II blue stain was determined by surface examination only and is therefore merely a rough comparison rather than an accurate determination.

TABLE II

MORTALITY ACCORDING TO BLUE STAIN AT POINT OF INJECTION

Blue stain	Heavy	Medium	Light	None
Number of trees	82	44	15	9
Average percent mortality	44.4	37.1	64.0	72.2



Even though the blue stain determinations leave much to be desired in the way of completeness, table II shows a tendency for mortality to be greatest where there was least blue stain coloration.

The difficulty of an accurate blue stain determination without felling the tree for examination is shown in the accompanying fifteen plates. These plates show the results of examination of 59 trees which were marked at the time of attack and felled as needed to represent 10-day attack periods. After each tree had been felled, it was cut into 16-foot lengths starting at three feet, and a diagram of the blue stain was drawn for each cross section. The tree number, age of the attack, width of the sapwood, tree diameter and height of the sample are shown for each tree. In addition, exposure of the tree to sunlight is indicated by arrows on the basal sections, the north side of the tree always being toward the top of the page. An attempt was also made to distinguish between light and heavy blue stain, by cross-hatching the light stain and indicating the heavy with solid black.

#### PLATE I

Before presenting the 15 plates containing the blue stain drawings, plate I is shown to demonstrate the irregular growth of blue stain and the rapidity with which it develops under optimum conditions. These photographs were made from a cross section of western white pine, cut from a tree which, on July 25, 1936, had been attacked for 30 days. This section was brought to the laboratory, kept under a moist cloth at room temperatures and photographed periodically. The course of development of the blue stain is shown in six photographs over a period of 11 days.

PLATE I

July 25, 1938



July 29, 1938



July 26, 1938



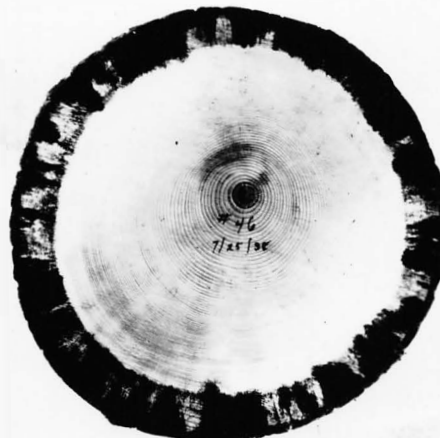
Aug. 1, 1938



July 28, 1938



Aug. 5, 1938



#### PLATES II, III & IV

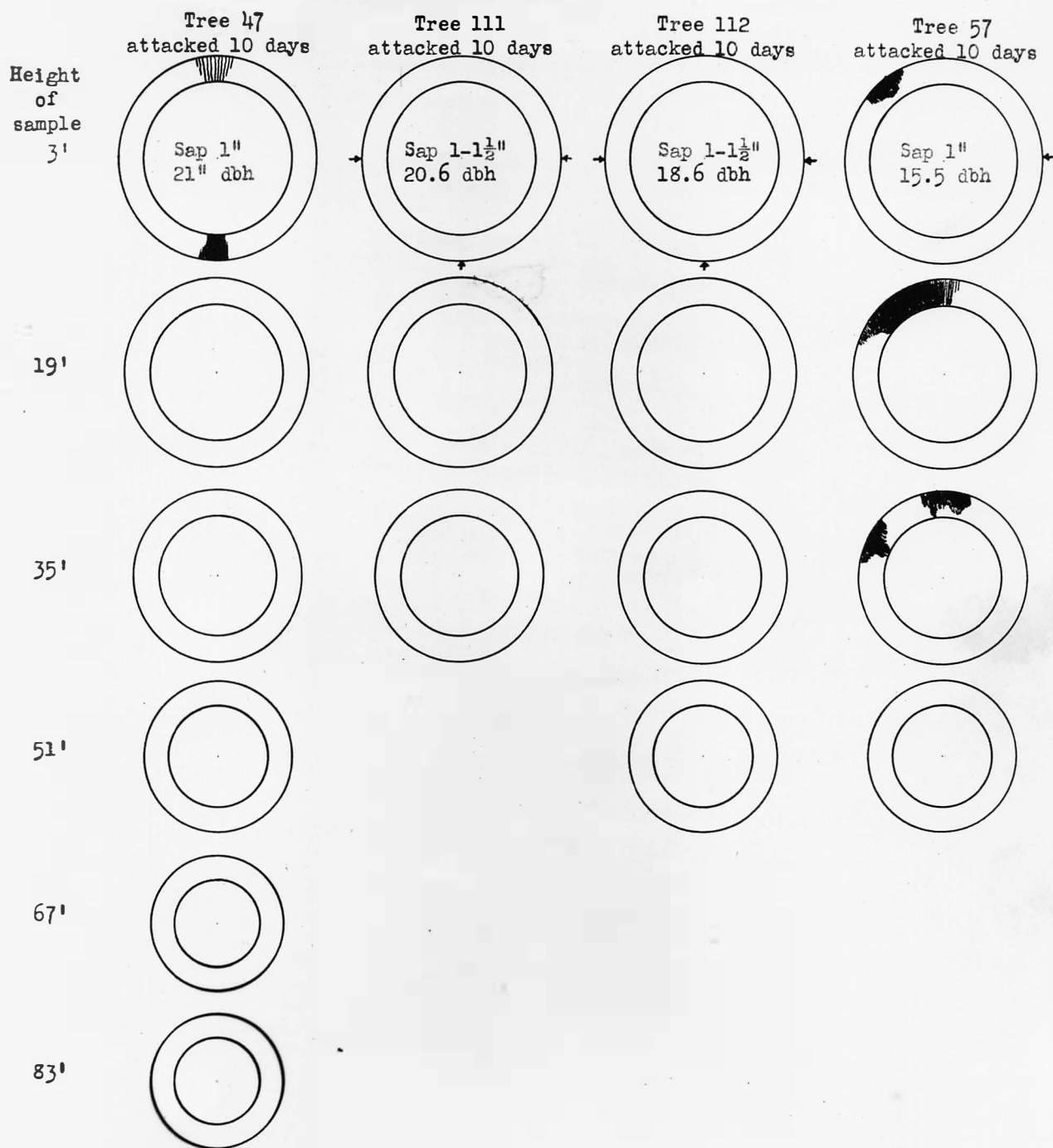
In these three plates, cross sections are shown from trees which had been attacked for ten or twenty days. Of the 12 trees in this group, only half of them show any blue stain development. In no case, however, does the amount of stain appear to be sufficient to prevent successful injection.

In all of the trees throughout this study, it will be seen that sunlight appears to have no great effect on blue stain, except in the case of tree 59, in which the 35-foot section, which was exposed to sunlight on the south, shows heavier stain than either of the two lower sections. This is also the only case which shows most abundant blue stain above the 3-foot or 19-foot sections. The lack of correlation between sunlight and blue stain development is to be expected, however, because in normal white pine stands very little sunlight filters through the crown canopy.



# PLATE II

## BLUE STAIN DEVELOPMENT IN WESTERN WHITE PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE

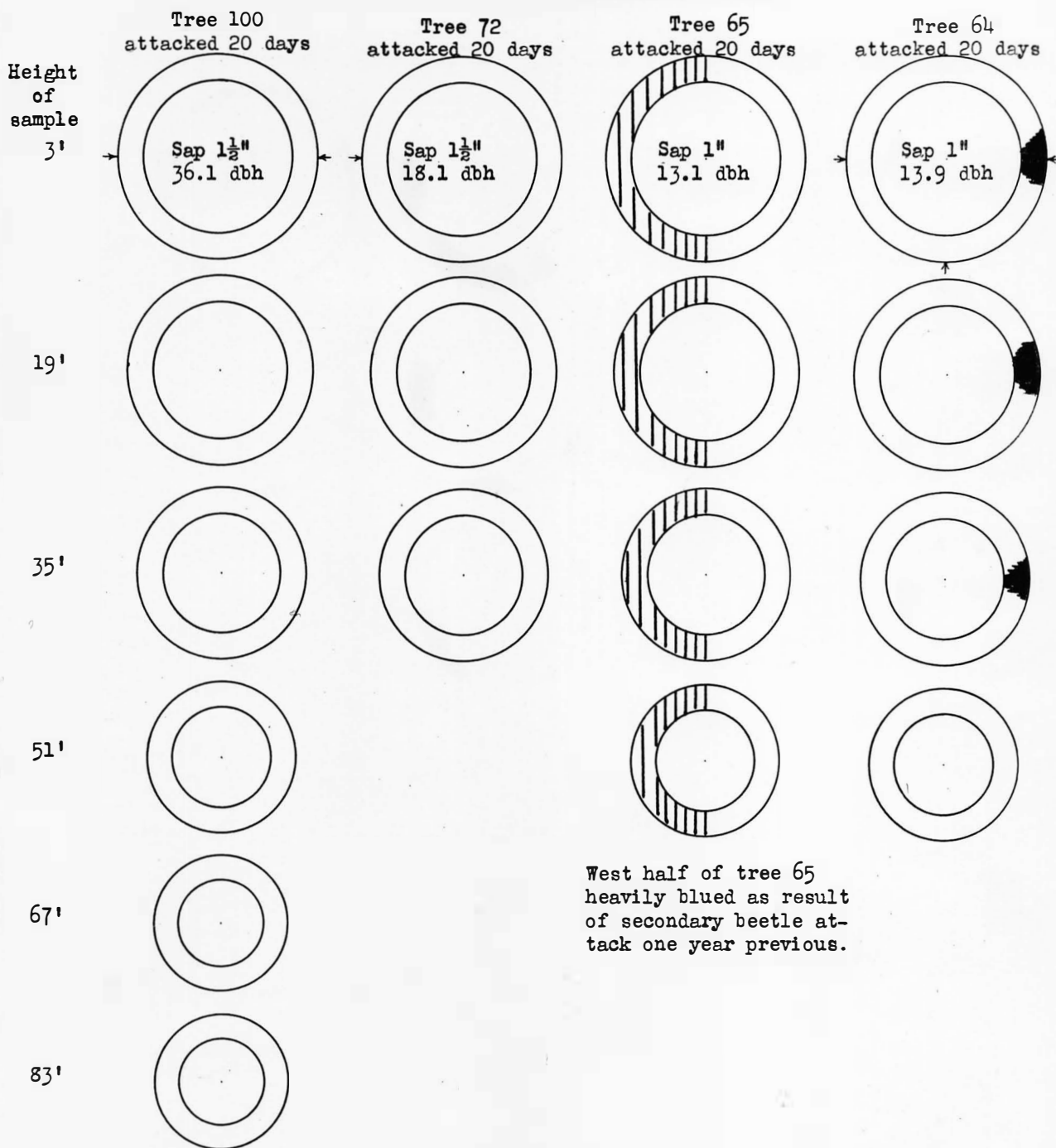
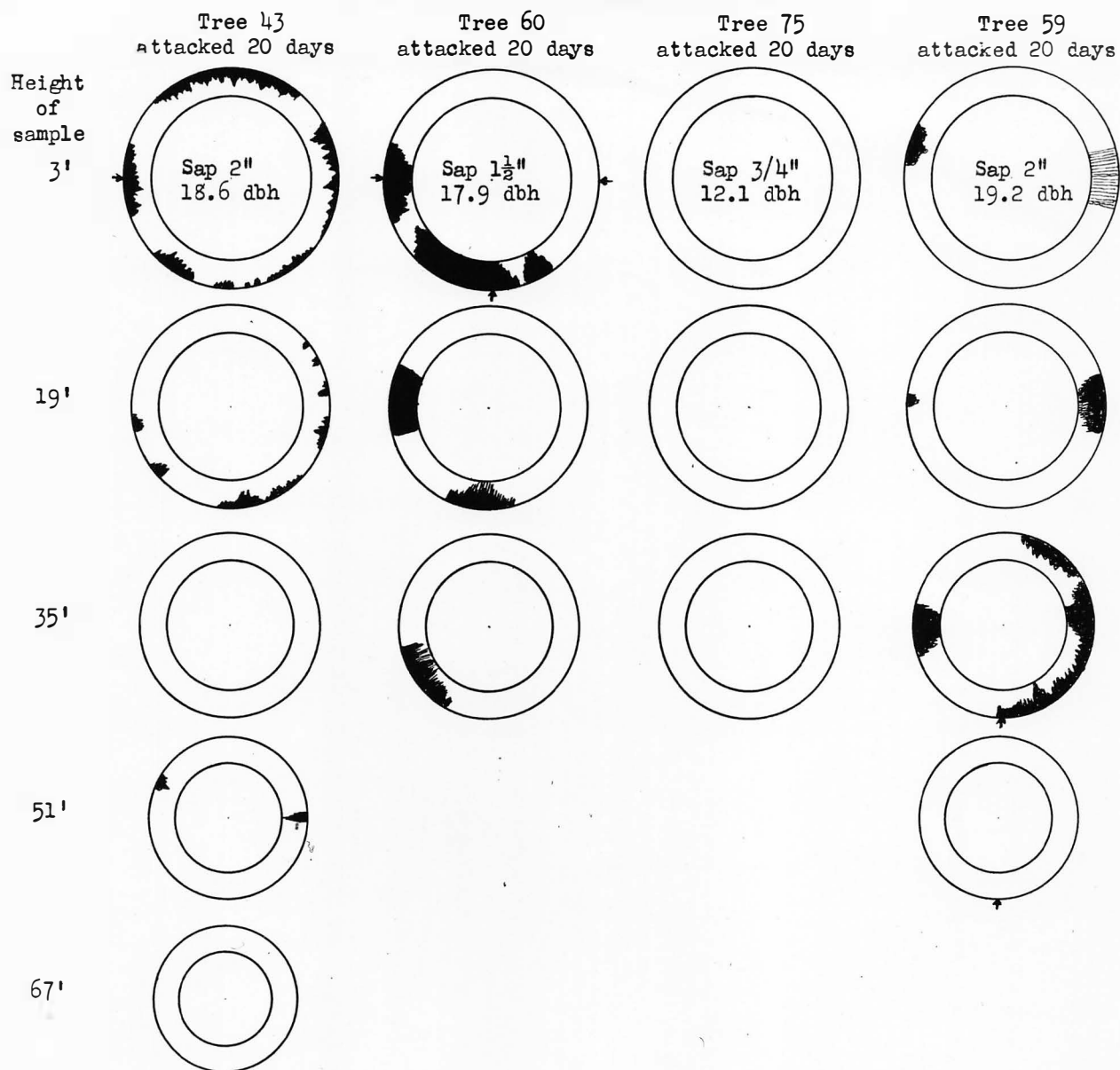


PLATE IV

BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE





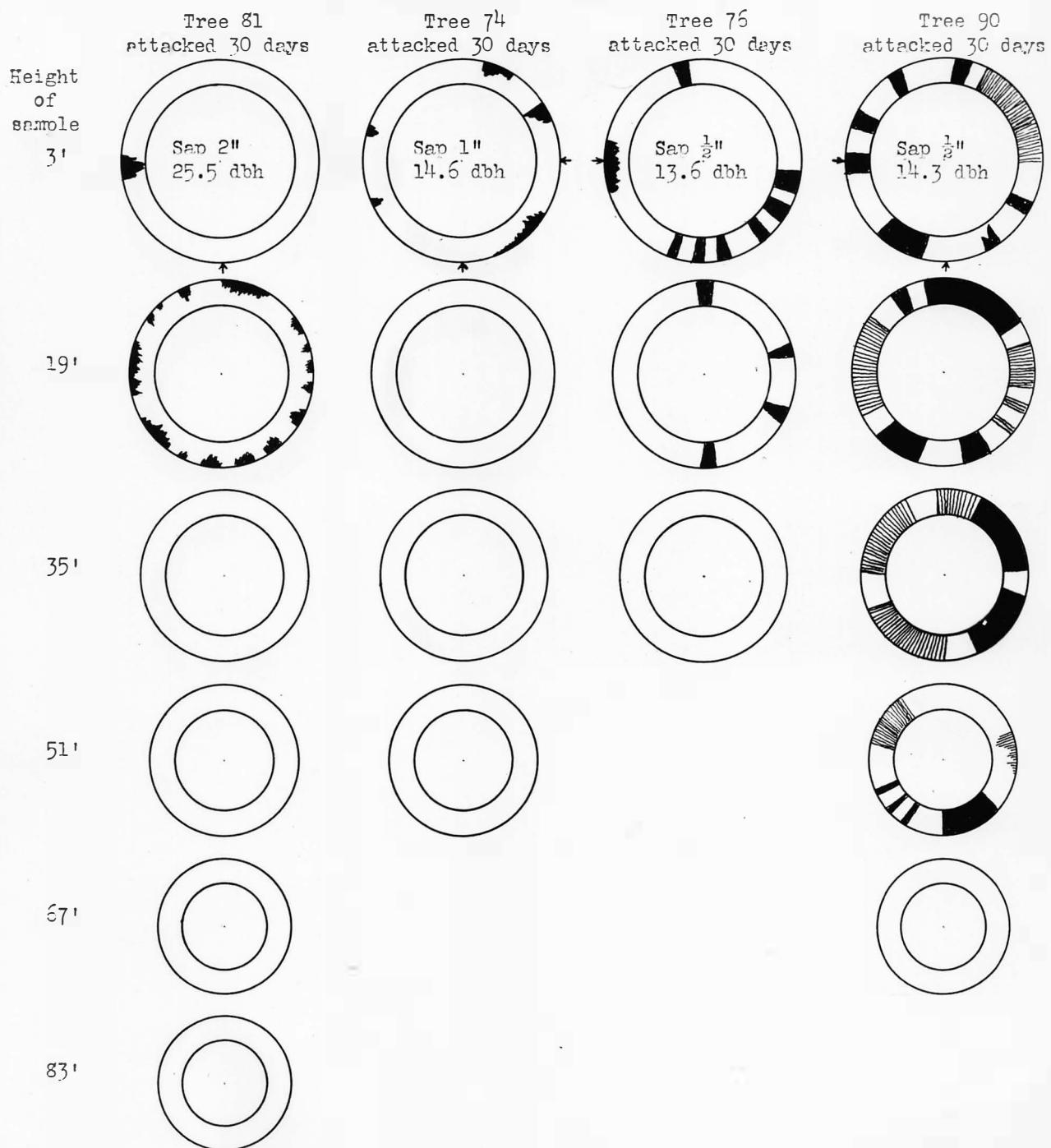
#### PLATES V, VI & VII

Most of the sections from trees attacked for 30 days show considerable blue stain development. However, in all but three cases, in which staining of the sapwood is complete at the 19-foot section, there is a large area of unobstructed sapwood.

Sunlight again appears to have no great effect upon blue stain development, neither as to side nor exposure of the entire tree. Shaded sides and shaded trees appear to show as much and in some cases more stain than sunny sides.

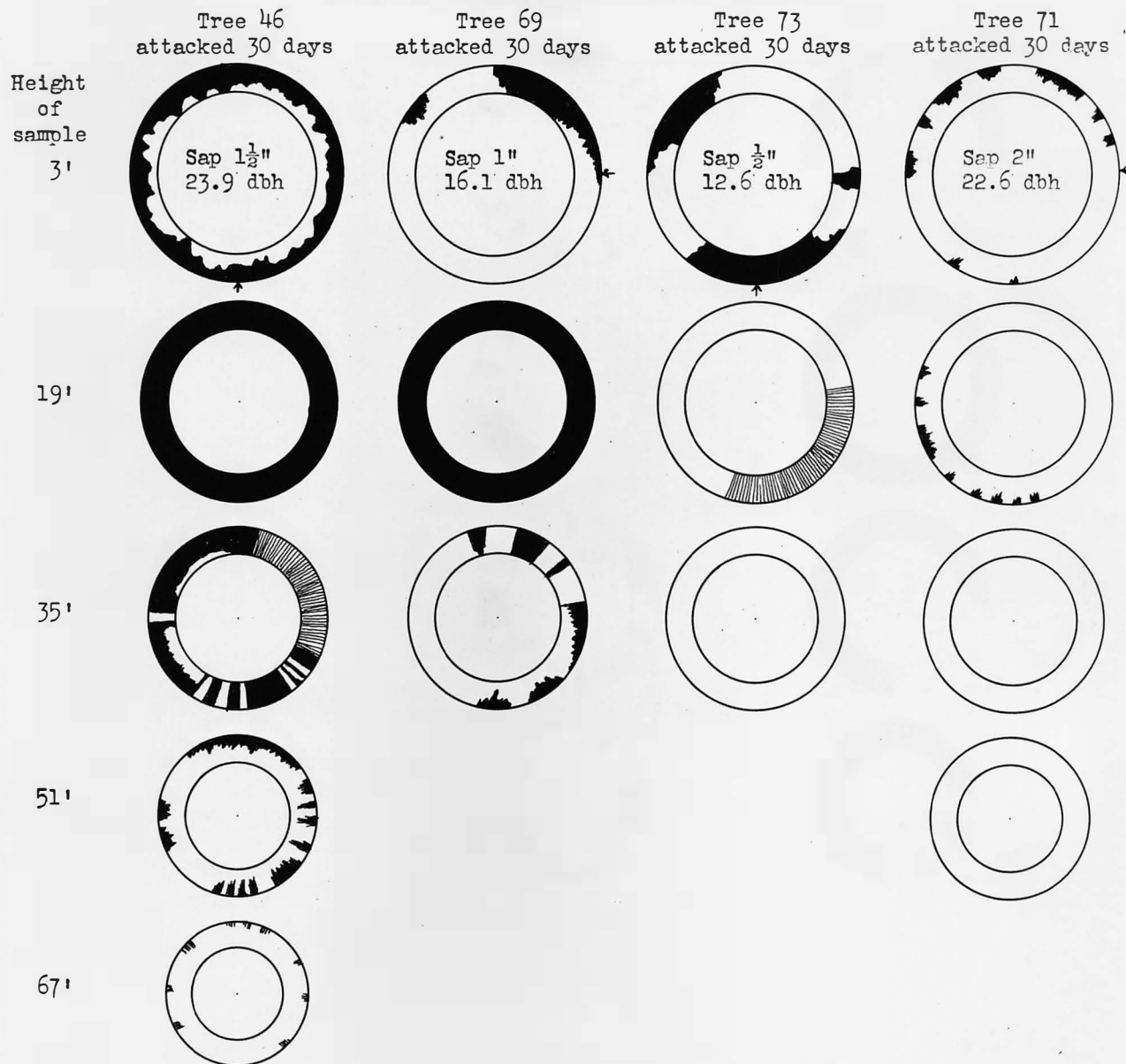
It is also apparent that in 30-day attacks greatest staining is present in the basal portion of the tree, either in the 3-foot or 19-foot section.

BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE

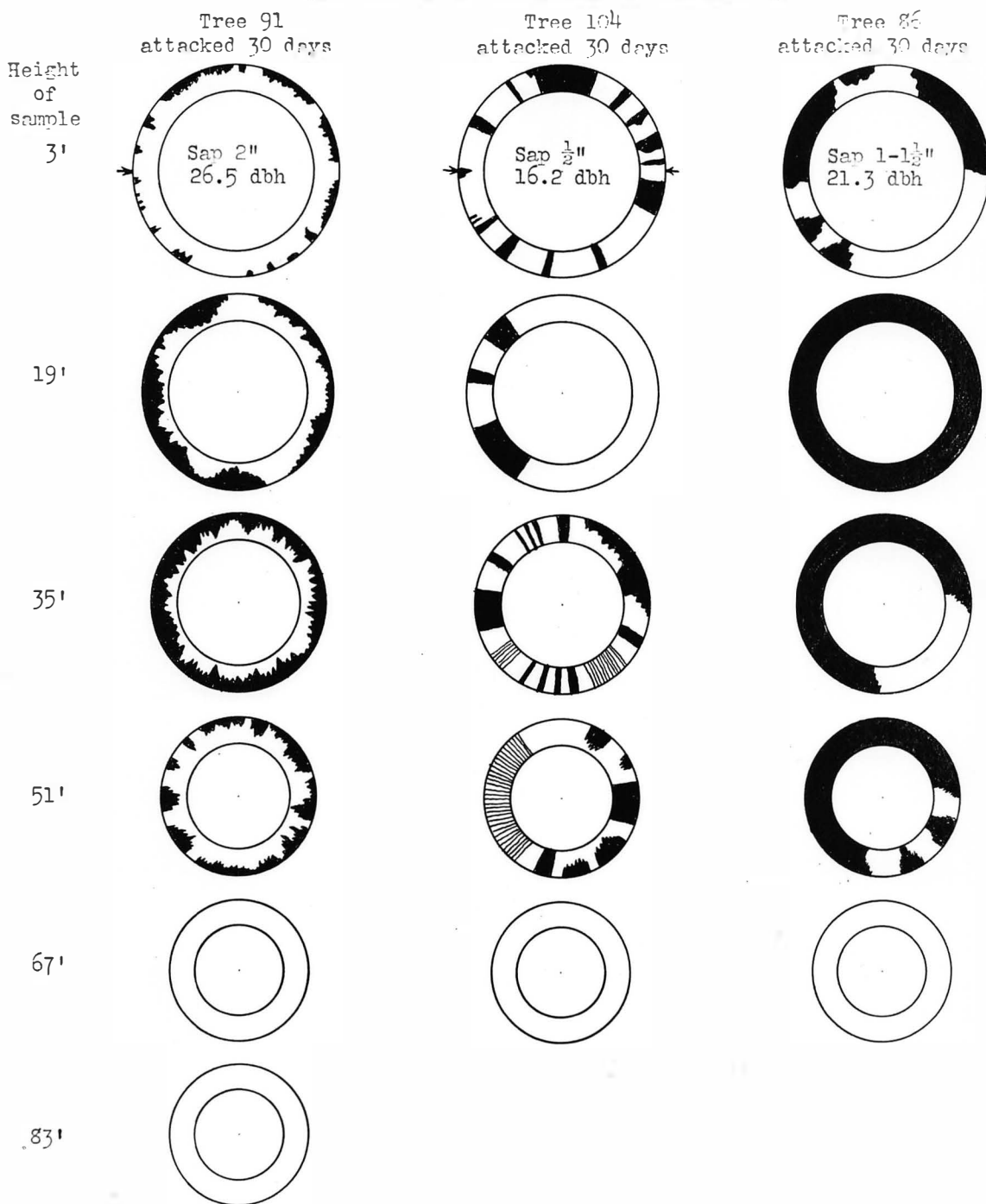


# PLATE VI

## BLUE STAIN DEVELOPMENT IN WESTERN WHITE PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



RING STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



PLATES VIII, IX & X

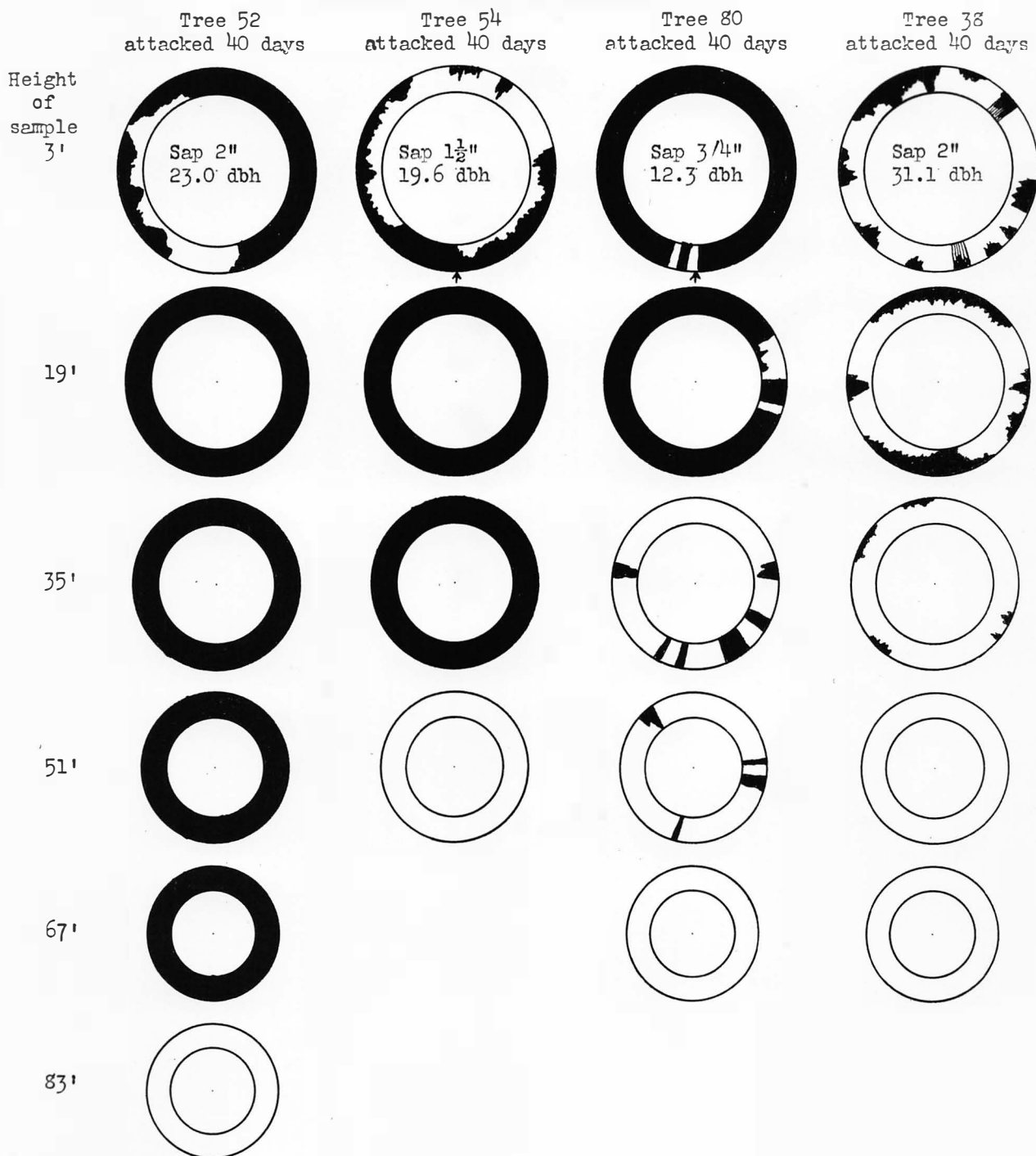
The sections from trees attacked for 40 and 50 days show a surprising range in amount of blue stain development. Trees 38 and 89 for example show no more stain than some of the trees attacked for only 10 or 20 days. Trees 44, 49, 52 and 88 show practically solidly stained sapwood.

Tree 80 serves as a good example of blue stain in a double attack. In western white pine the basal portion of the tree is attacked first, followed by attack of the upper portion. In tree 80, there apparently was a considerable elapse of time between the two attacks, and as a result there is very little blue stain above the 19-foot section.

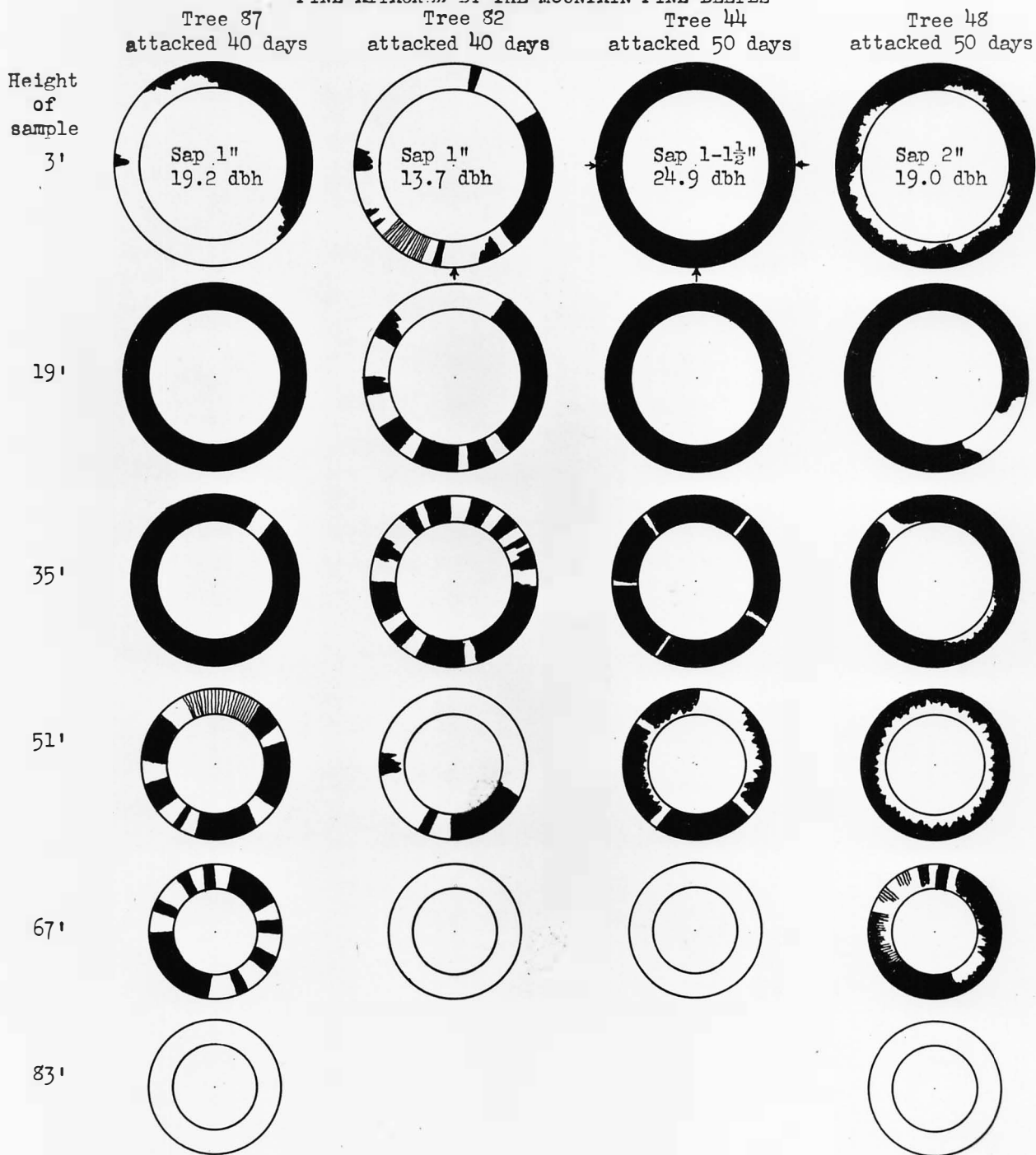
At 40 and 50 days after attack it is noticed that blue stain in the 3-foot section has not developed as rapidly as in the 19-foot section.



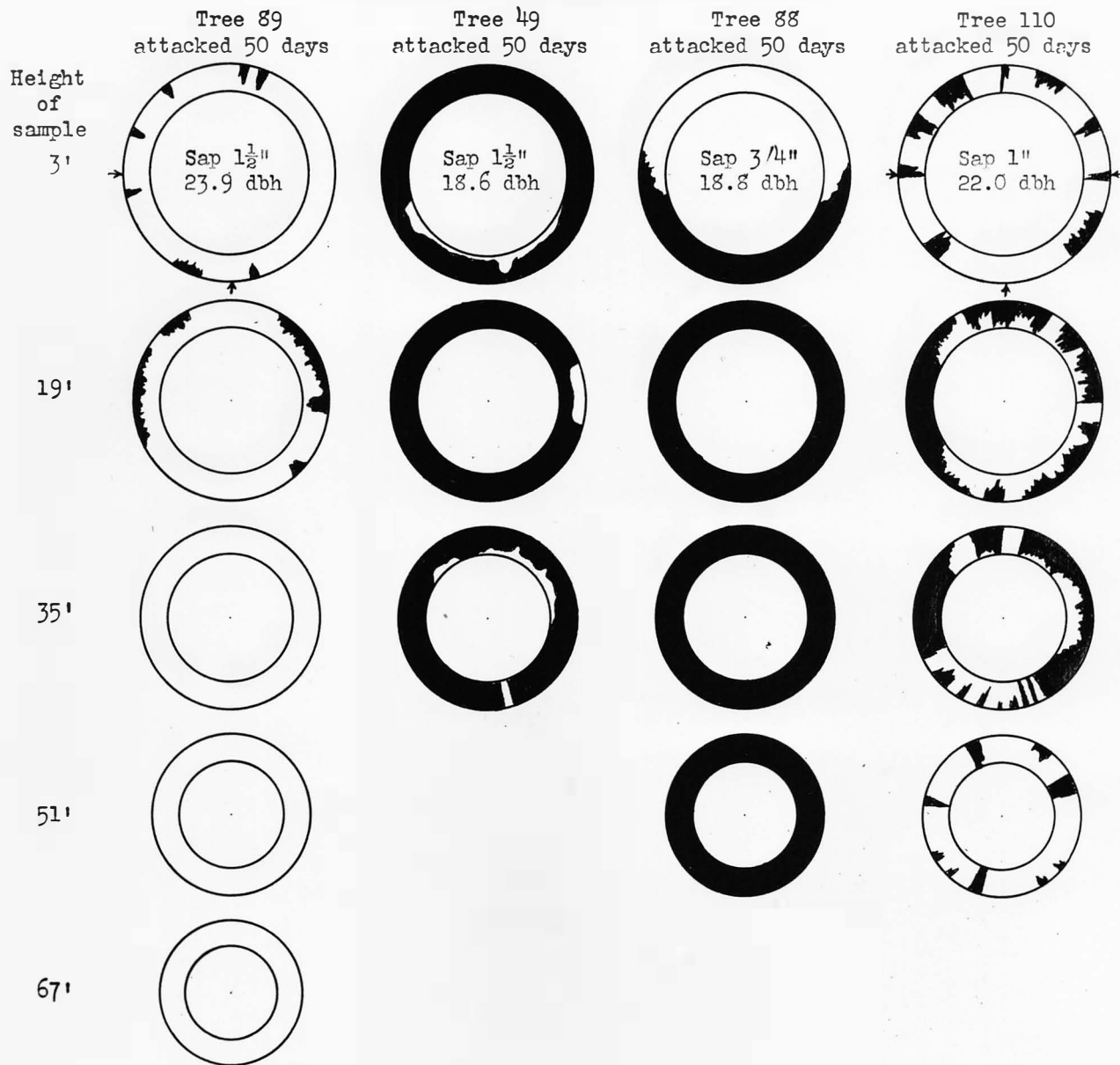
BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



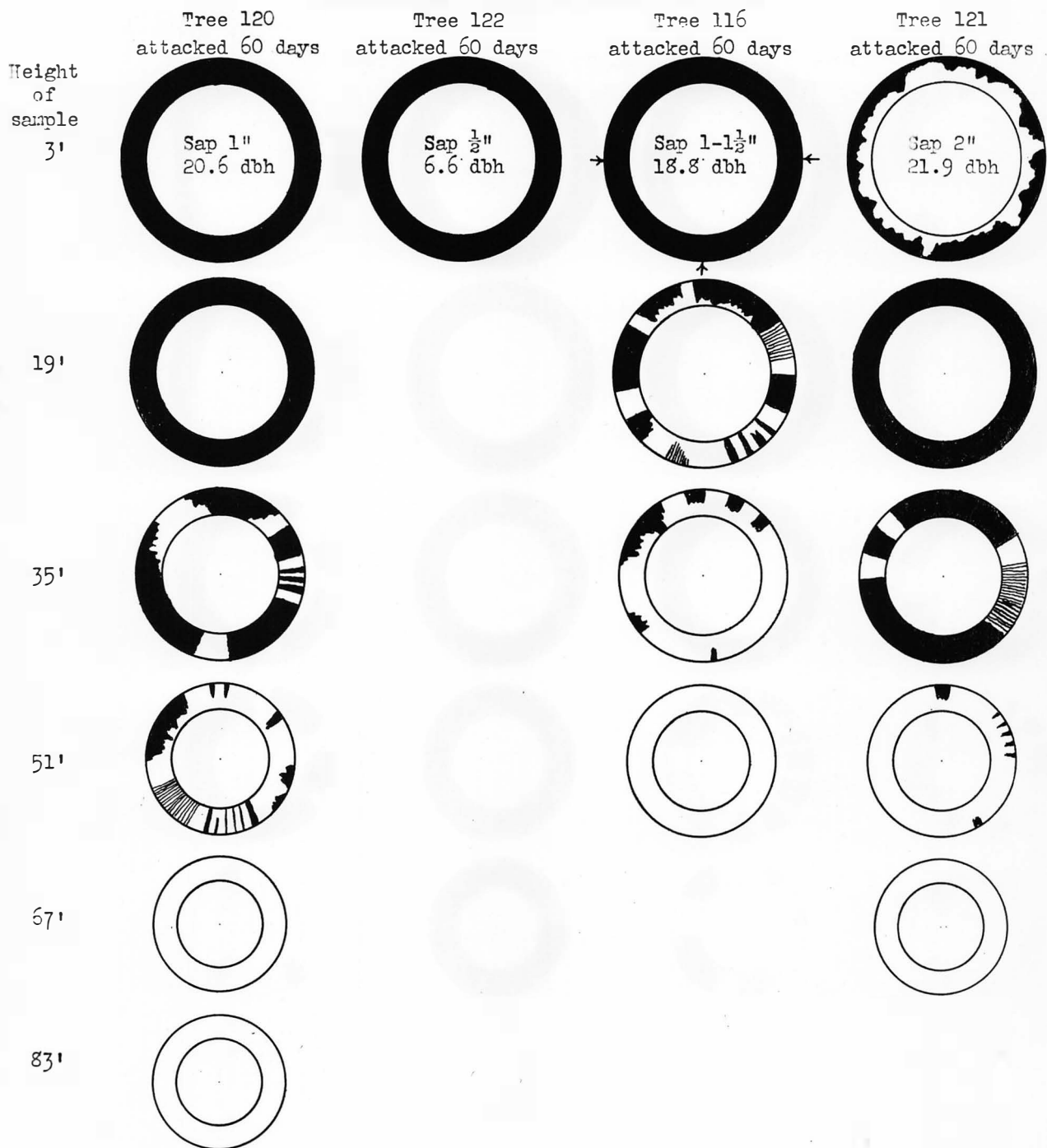
BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



PLATES XI, XII, XIII, XIV, XV & XVI

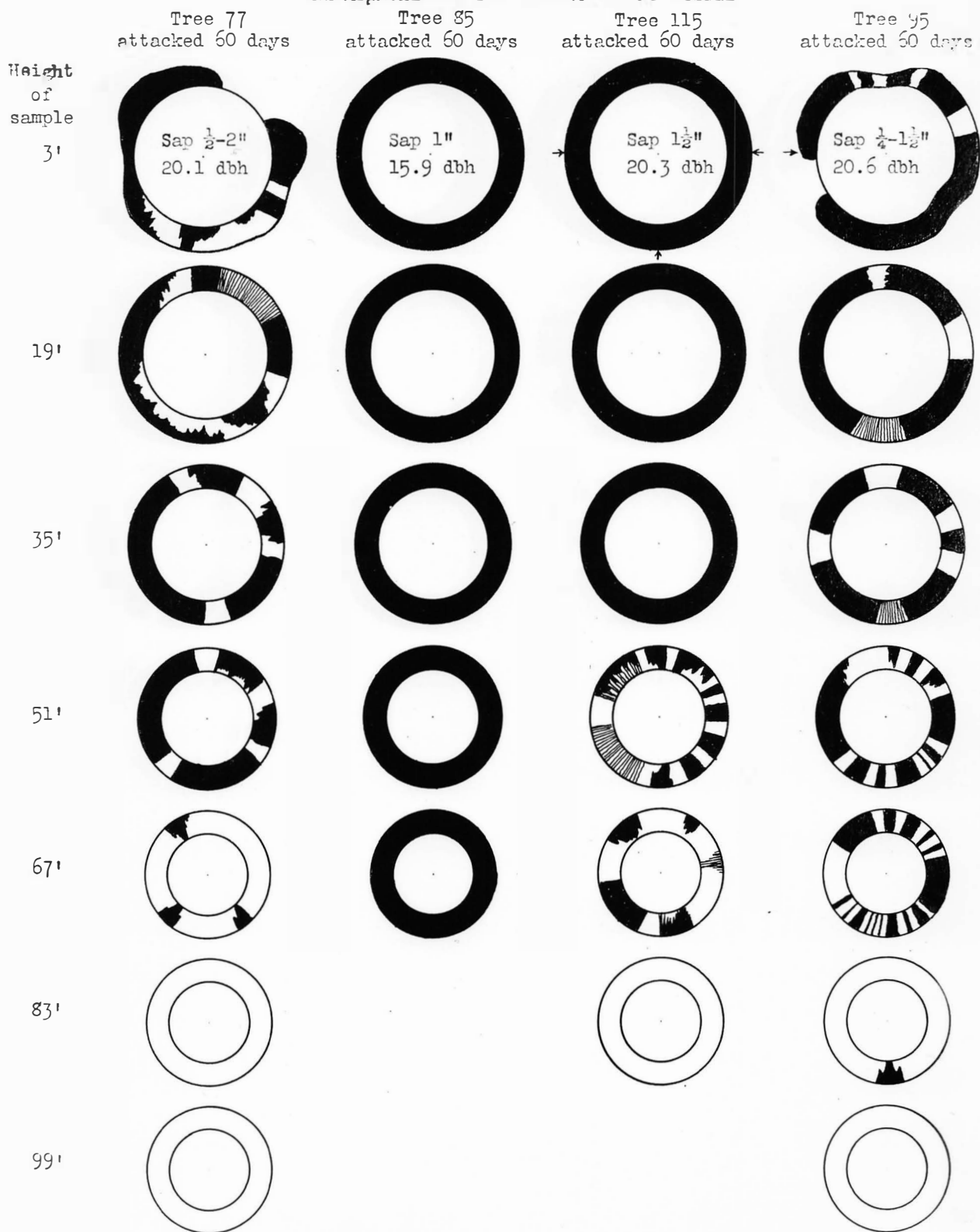
The last six plates show cross sections from trees in which the attacks are 60 days old or older. In these, 15 of the 24 trees have complete bluing of the sapwood at three feet. Of the remaining six trees, three show complete bluing at 19 feet and three show partially unobstructed sapwood throughout the total infested length.

BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE

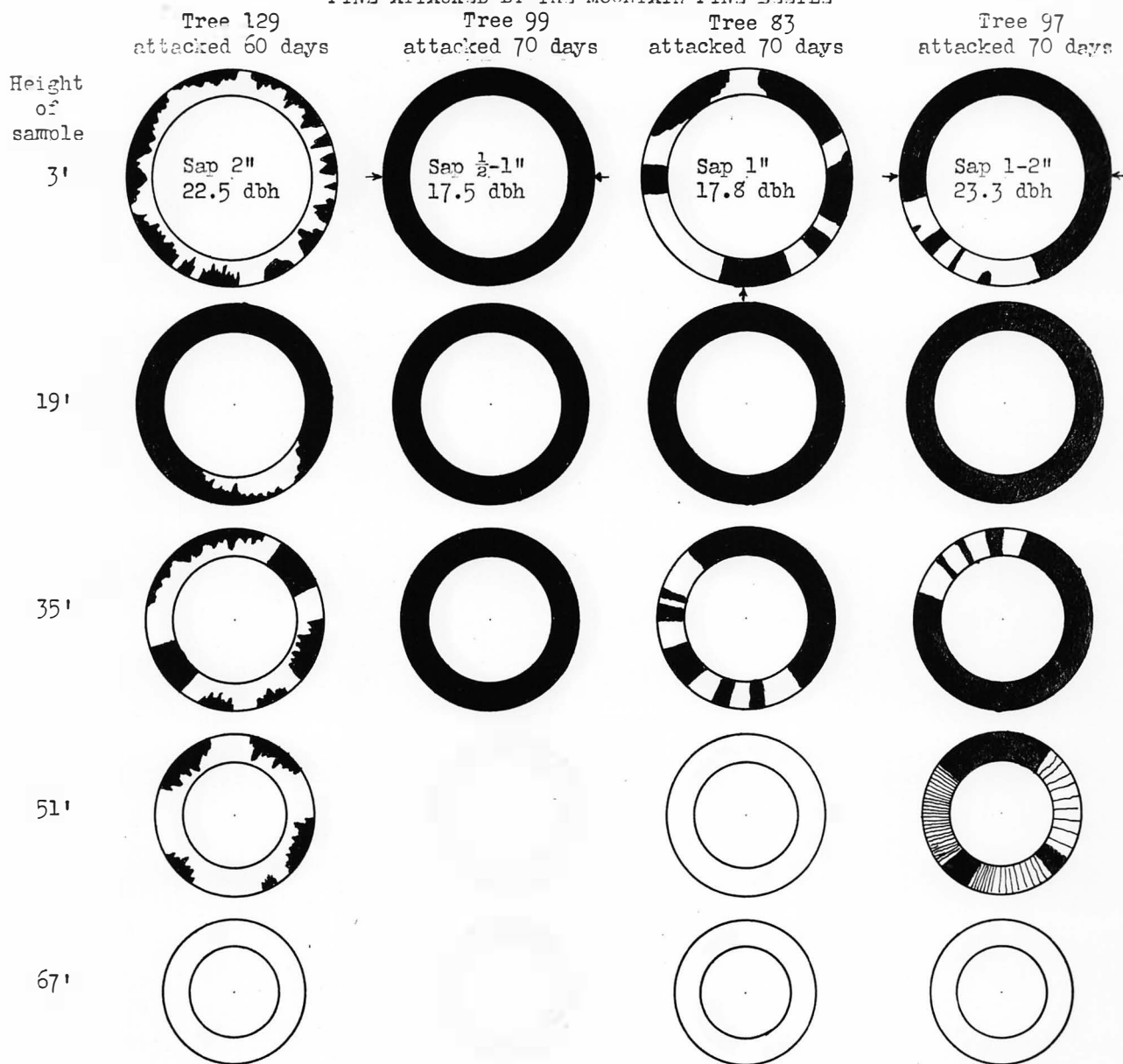




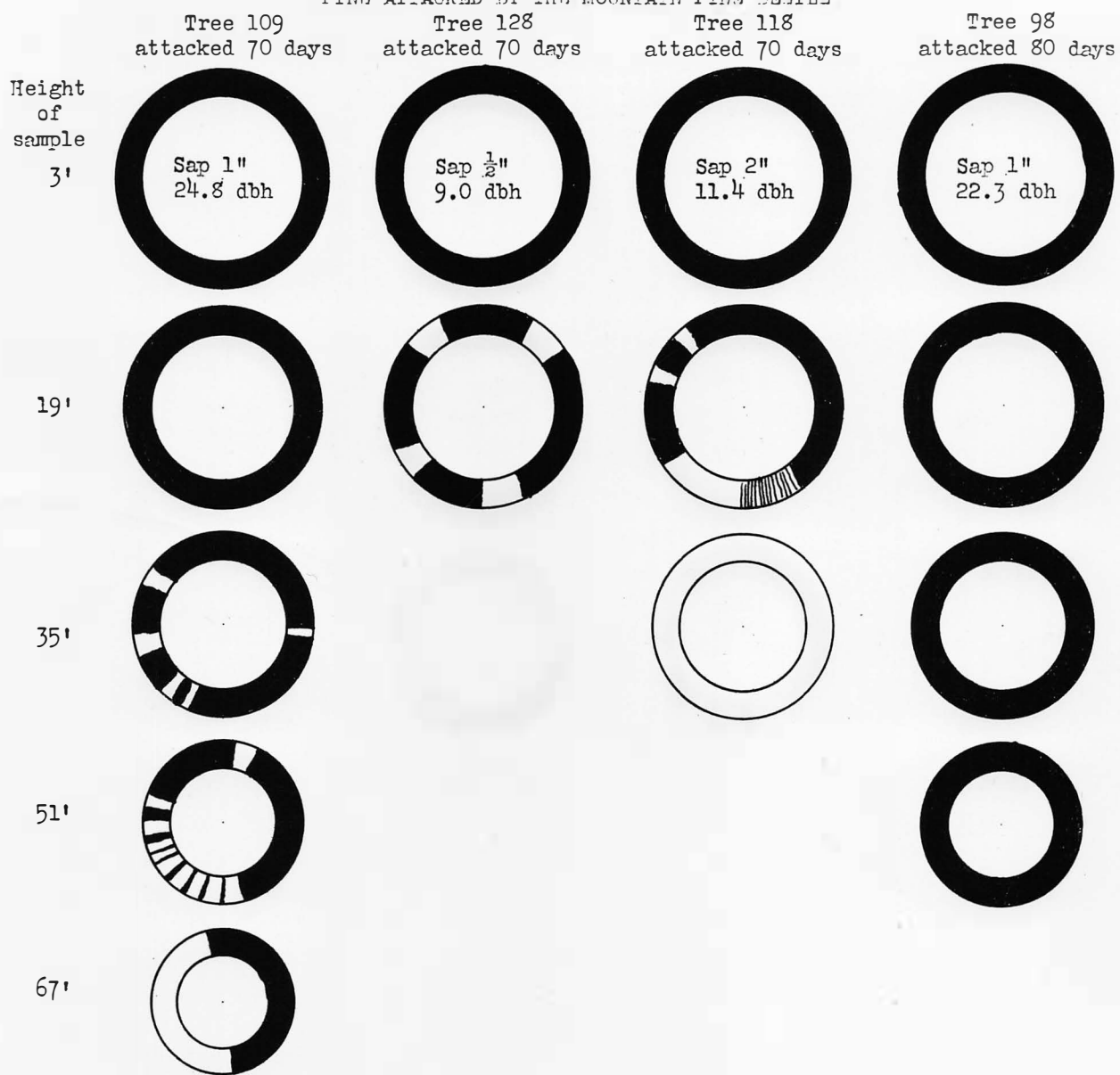
BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



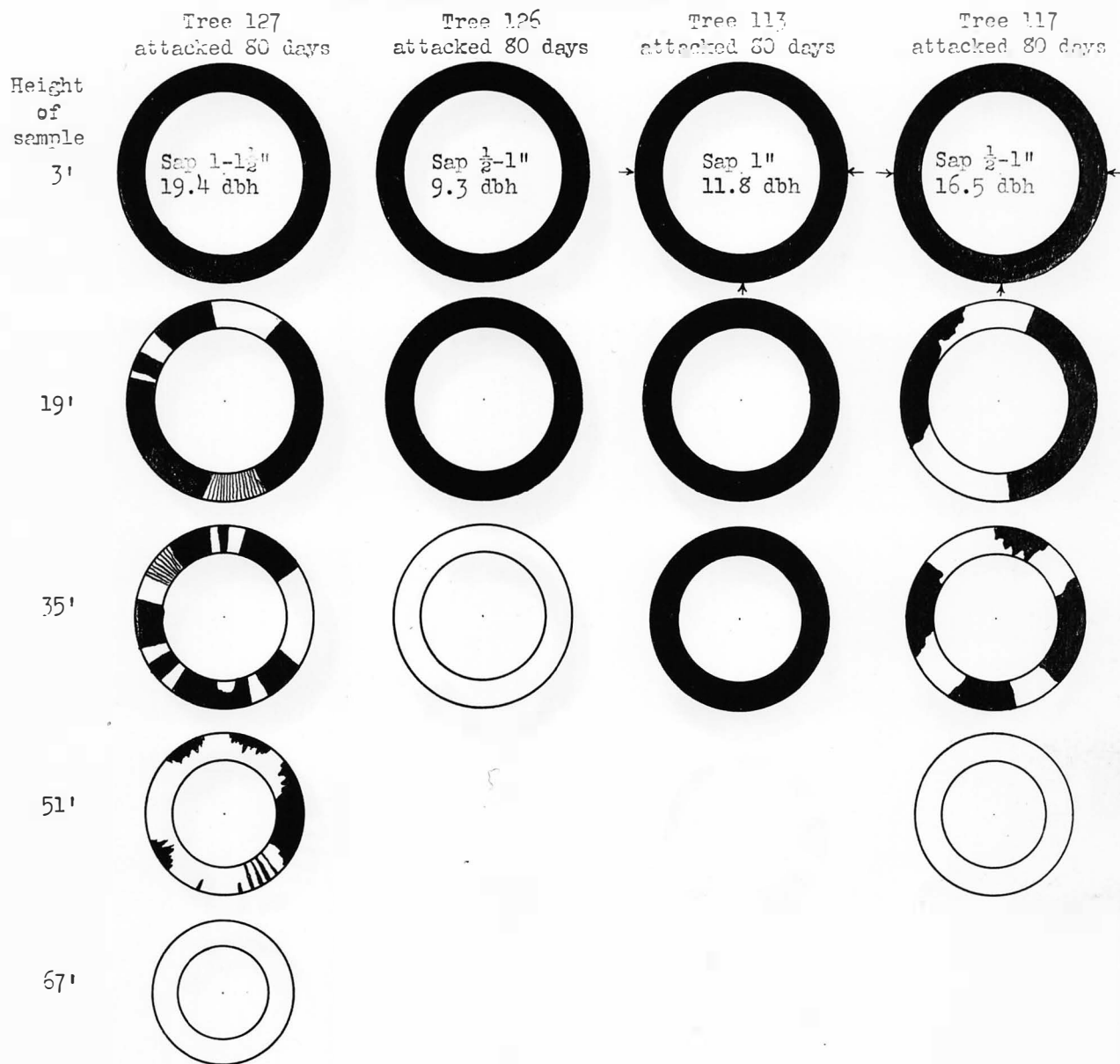
BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE

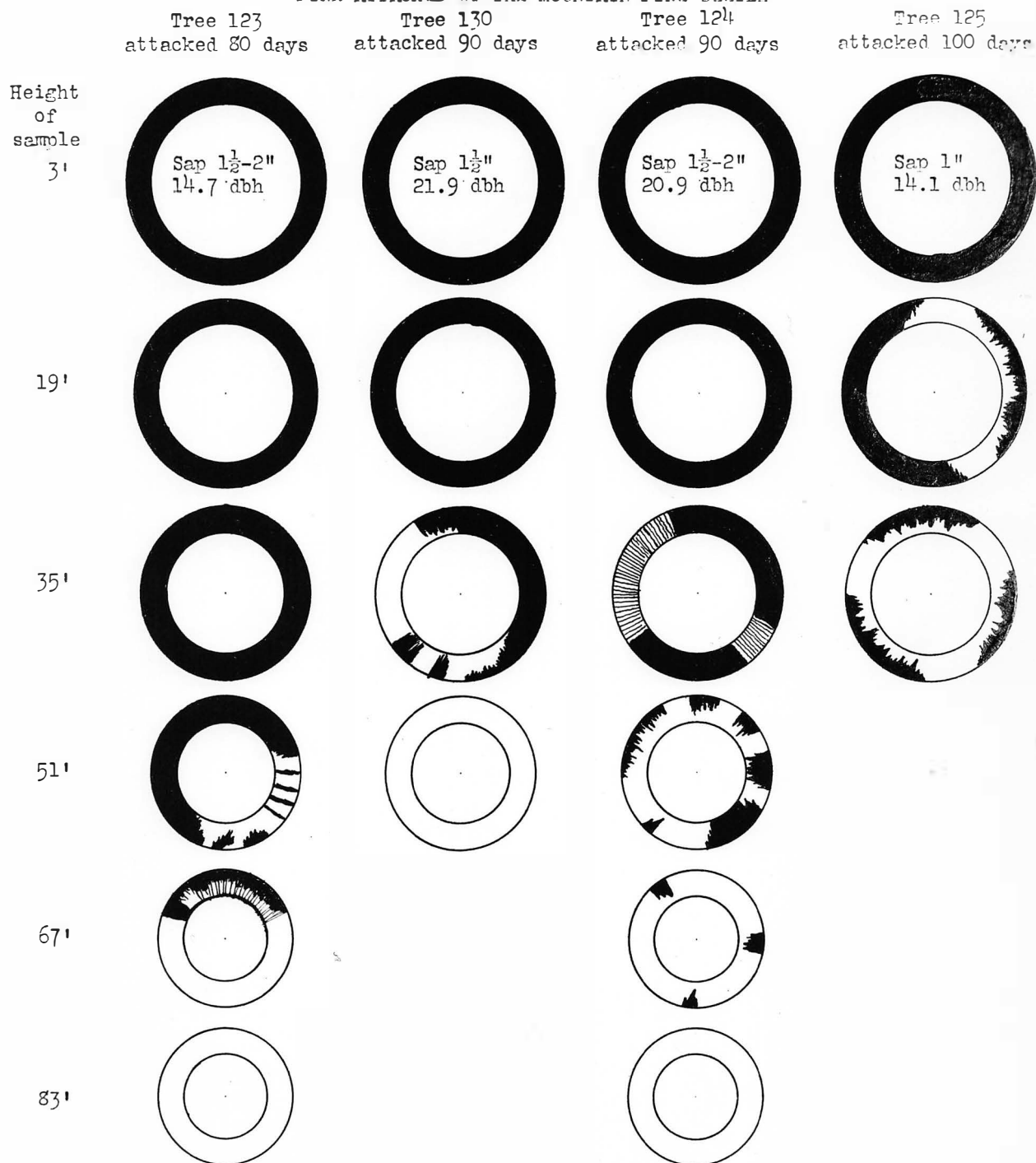


BLUE STAIN DEVELOPMENT IN WESTERN WHITE  
PINE ATTACKED BY THE MOUNTAIN PINE BEETLE



# PLATE XVI

## BLUE STAIN DEVELOPMENT IN WESTERN WHITE PINE ATTACKED BY THE MOUNTAIN PINE BEETLE





It is obvious from the preceding photographs and drawings that blue stain is an exceedingly difficult factor to evaluate, an accurate determination of which would necessitate felling and sectioning the tree and thus prevent its use for tree-injection purposes.

The cause of the irregularity in blue stain development is difficult to determine. Solar heat apparently does not have as great an effect as was believed, judging from the condition shown in the preceding drawings. It was thought that abundance of inoculations, judged by the number of attacks and wood density, might have an important influence. Table III shows the average of these two factors according to the amount of staining in the different age of attack groups. Although "heavy" and "light" are the terms used in table III to designate the abundance of blue stain in the 10- and 20-day age groups, the presence or absence of stain was the actual separation used, while in the 60- and 70-day groups the trees were separated on the basis of completely or incompletely blue-stained sapwood. It was felt that the trees with attacks 80 days old or older did not show sufficient difference in blue stain and were consequently excluded from this table.

TABLE III

ANNUAL RINGS IN LAST HALF-INCH OF WOOD AND MOUNTAIN  
PINE BEETLE ATTACKS PER SQUARE FOOT ACCORDING TO  
ABUNDANCE OF BLUE STAIN

	Age of Attack									
	10 days		20 days		30 days		40 days			
Blue stain	Rings	Attacks	Rings	Attacks	Rings	Attacks	Rings	Attacks		
	:	:	:	:	:	:	:	:		
Heavy	18	7.6	14	3.2	14	4.4	19	4.0		
	:	:	:	:	:	:	:	:		
Light	21	2.9	24	7.2	24	6.7	24	3.6		
	:	:	:	:	:	:	:	:		
	50 days		60 days		70 days					
	Rings	Attacks	Rings	Attacks	Rings	Attacks				
	:	:	:	:	:	:	:	:		
Heavy	43	3.8	20	7.9	24	5.0				
	:	:	:	:	:	:	:	:		
Light	16	2.6	13	7.0	14	5.5				

Table III indicates that neither wood density nor attacks per square foot have any great influence on abundance of blue stain or rapidity of its development. There remains therefore very little of a definite nature that can be concluded from the preceding study except that (1) blue stain is most abundant in the base of infested western white pine, (2) blue stain is very irregular in its development, and (3) although dependent on duration of time after attack, blue stain shows considerable variation in time required to permeate the entire sapwood.

### Effect of Age of Attack

Closely associated with blue stain, since blue stain development is dependent upon it, is the effect which age of the attack has upon successful injection. Table IV presents data concerning the average mortality secured in the different age of attack groupings.

TABLE IV  
MORTALITY ACCORDING TO AGE OF THE ATTACK

Age of	:	:	:	:	:	:	:	:
attack	:	:	:	:	:	:	:	:
in days	: 17-29	: 30-39	: 40-49	: 50-59	: 60-69	: 70-79	: 80-89	: 90-99
Number of:	:	:	:	:	:	:	:	:
trees	: 13	: 14	: 9	: 39	: 52	: 19	: 4	: 5
Average	:	:	:	:	:	:	:	:
mortality	: 39.6	: 65.0	: 43.3	: 48.8	: 37.4	: 44.7	: 65.0	: 60.2

The variation in mortality shown in table IV probably results from the irregular blue stain development discussed in the preceding section. It is interesting to note, however, that the mortality secured in the older attacks was as good as that resulting from injection of the younger attacks. Obviously, there must be some penetration of the poison through the blue-stained areas, because of the fact that throughout all of the injection work fairly good results were obtained in the older age groups.

### Effect of Depth of Saw Kerf

Two tests were made to determine the feasibility of introducing the poison in back of the blue stain by means of a deep saw cut. In the first test, two small green trees and one infested tree attacked for 57 days were injected with copper sulfate and the ascent of the poison was determined by periodic examinations. At each examination an increment core was taken at five-foot intervals up the tree, and the core tested with potassium ferrocyanide to determine the presence and location of the poison.

In the first green tree, the poison was first noticed at five feet (three feet above the collar) five hours after injection. It was found in a narrow band one sixteenth inch wide, one quarter inch in from the outer surface of the wood. In another hour the band had widened to one quarter inch and at the end of 22 hours all of the one-half inch of sapwood contained copper. Poison was first apparent at the 10-foot height 22 hours after injection in the form of a sixteenth-inch band one-eighth inch in from the surface of the wood. This band had widened to one-eighth inch 46 hours after injection and had permeated all of the sapwood after 70 hours. At a height of 15 feet the poison appeared in a sixteenth inch band at the surface of the wood 46 hours after injection and the band widened to one quarter inch 96 hours after injection. After an elapse of four



days, a sixteenth-inch band of poison was found at 20 feet and on the fifth day it was noticed that there was a radial movement of the poison into the phloem. The copper found in the phloem could not have gone to the foliage and back down the phloem because it had reached a height of only 20 feet which was considerably below the lowest branches.

The second tree, a 3-inch green western white pine, was selected in order to trace the complete course of the poison throughout the tree. In this case, poison was first noted four hours after injection at 5 feet (four feet above the collar) in a sixteenth-inch band one-eighth inch in from the surface of the wood. In another hour it was found in all of the quarter-inch of sapwood at five feet, and six hours after injection was found at 10 feet in a sixteenth-inch band, one-eighth inch in from the surface. At the end of 22 hours, copper was found to have permeated all of the sapwood throughout the stem of the tree (15 feet) and was found throughout the sapwood of the lower branches which were at 10 feet. Two days after injection, copper was found throughout the tree in all of the active xylem, both in stem and branches. Three days after injection no change had occurred except that copper was found in the phloem at 10 feet. After five days, copper was found throughout all of the active xylem and phloem in the tree.



The third tree was a 12-inch infested tree which showed considerable blue stain development. The first trace of copper was found two days after injection in an eighth-inch band at the surface of the sapwood at five feet. Four days later another band one-quarter inch wide had appeared one-half inch in from the surface and a very narrow band was present on the surface of the sapwood at ten feet. No further change occurred until the eighth day after injection when the outer quarter inch of sapwood at 15 feet showed the presence of copper. At this time also, the last of the solution left the collar. No great amount of change occurred throughout the remainder of the time this tree was tested. The poison reached 20 feet in 11 days, 25 feet in 18 days and had reached 30 feet on the 28th day when the last test was made. Upon examination the following spring, it was found that the poison had reached a height of 45 feet, but was spotty in distribution throughout the entire distance. The tree was infested to a height of 40 feet and showed an 80 percent mortality.

This portion of the study indicated that the poison did not follow a definite path up the stem of the tree and could conceivably follow a path to avoid blue stain where these fungi had obstructed the conducting tissues. Forty trees were selected, therefore, to test the effect of deep and shallow saw kerfs. Twenty trees had been attacked from 27 to 30 days and half of these were injected by means

of a kerf one-half to one inch deep, while the remaining 10 trees were injected through a shallow cut less than one-quarter inch deep. Similar treatment was given to the twenty trees representing the 50 to 59-day old attacks. Table V shows the results of these tests.

TABLE V  
MORTALITY ACCORDING TO DEPTH OF SAW KERF

Depth of saw kerf	Age of attack	
	27 to 30 days	50 to 59 days
$\frac{1}{2}$ -1"	41.6	25.5
$\frac{1}{4}$ "	63.7	44.7

The data presented in table V show that the deep saw kerf had an opposite effect from that anticipated. The shallow kerf showed better results in both the older and younger attacks.

#### Effect of Dry Side.

Many of the trees injected during the 1937 work possessed a "dry side" which resulted from such causes as root fungi or sun scald. These dry-sided trees are common on certain western white pine sites and are usually infested with secondary bark beetles and wood borers on the affected side, with mountain pine beetle on the green side. It was thought that this condition of the tree might have some influence on the success of the injection so that table VI has been prepared to compare the mortality secured in normal and dry-sided trees.

TABLE VI  
MORTALITY ACCORDING TO DRY SIDE

Dry side	Trees	Average age of attack	Average mortality
	no.	days	percent
Present	58	56.5	62.2
Absent	72	51.7	43.3

It is readily apparent in table VI that the dry-sided trees showed the greater mortality in spite of the fact that the average age of the attack in these trees was greater.

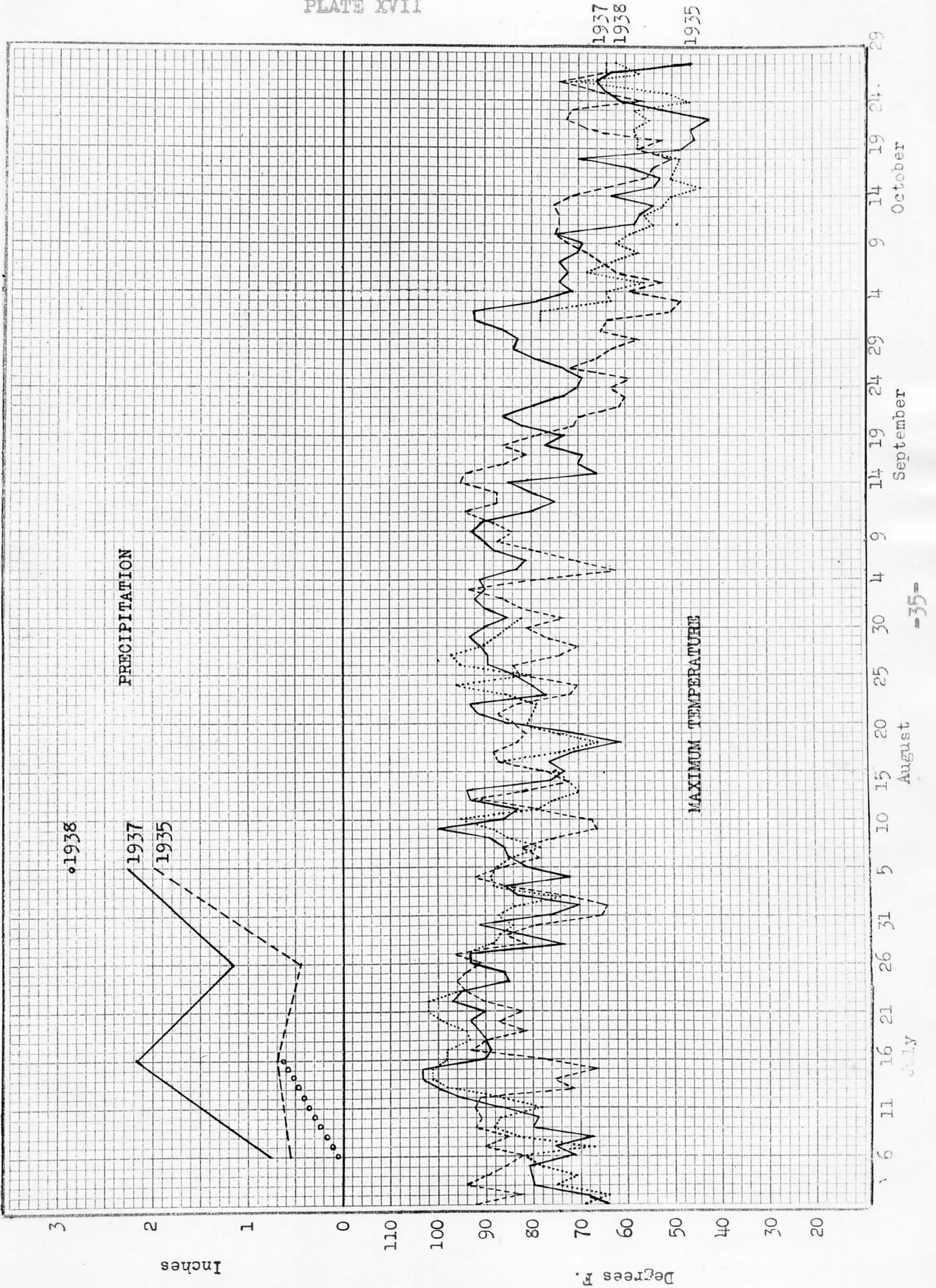
#### CONCLUSIONS

Results from injections up to and including the 1937 work have been so varied that it is difficult to know what definite conclusions can be made from the study. It is certain that excellent results were secured from the 1935 work when each tree was given a dosage comprising eight ounces of copper sulfate dissolved in one gallon of water. However, a similar treatment in 1937 yielded the poorest results ever obtained.

Considering blue stain as the critical factor, and moisture and temperature as the dominant controls of blue stain development, plate XVII shows maximum temperatures and precipitation during July, August, September and October for 1935 and 1937. The same data for 1936 have been included in order to compare the 1936 blue stain development with the other two seasons. In these charts it is seen that the 1935 and 1936 seasons were fairly comparable as to temperature and

# PLATE XVII

July August Sept. Oct.





moisture with the exception of the October precipitation in 1938. This, however, does not influence the blue stain study, because all examinations were made prior to October 1. The 1937 season was slightly cooler than the other two and showed considerably more rainfall. It is probable that with the unusual amount of rain during July and August there was more blue stain in the 1937-attacked trees than in either 1935 or 1938. However, the blue stain development in 1935 and 1938 must have been fairly comparable and it has been shown that in 1938 there was a considerable amount of stain in trees which had been attacked for more than 30 days. It is logical to assume that there was at least this amount of stain in the 1935 trees and that it did not prevent successful injection unless, by chance, all of the trees injected during 1935 were of the type in which the stain made a very slow development. It does not seem reasonable, however, that one could select between 300 and 400 trees which showed retarded blue stain development as late as September, unless <sup>Some climatic</sup> condition, not apparent in plate XVII, was the cause.

Moisture undoubtedly plays an important role in the development of blue stain. It might be well, in any future work of this nature, to secure wood samples for moisture determinations. There is no doubt that inability to make an adequate determination of blue stain in each tree at the time of injection is an important factor in preventing

discovery of the limits within which tree injection can be used in western white pine.

Respectfully submitted,

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